Modeling Planar Burnthrough and Adiabat Experiments using *DRACO*

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This paper presents results of the analysis of two types of spectroscopic planar-foil experiments using *DRACO*. *DRACO*[1] is an arbitrary Lagrangian-Eulerian (ALE) code designed to run in one, two, and three dimensions in planar (cartesian), cylindrical, or spherical geometry, which has recently been enhanced by the addition of interface tracking and radiation transport. By coupling to the Spect3D radiation postprocessor we are able to simulate (1) the emission of a burnthrough layer (which is used to experimentally assess the amount of multimode laser imprint) and (2) the absorption and emission from a buried witness layer (which is used to assess the amount of preheat induced by shock and radiation). This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC03-92SF19460.

1. D. Keller *et al.*, Bull. Am. Phys. Soc. **44**, 37 (1999).

Abstract

This paper presents results of the analysis of two types of spectroscopic planar-foil experiments using *DRACO*. *DRACO* [D. Keller *et al.*, Bull. Am. Phys. Soc. 44, 37 (1999)], which is an arbitrary Lagrangian-Eulerian (ALE) code designed to run in one, two, and three dimensions in planar (Cartesian), cylindrical, or spherical geometry, which has recently been enhanced by the addition of interface tracking and radiation transport. By coupling to the Spect3D radiation postprocessor we are able to simulate (1) the emission of a burnthrough layer (which is used to experimentally assess the amount of multimode laser imprint) and (2) the absorption and emission from a buried signature layer (which is used to assess the amount of preheat induced by shock and radiation).

Summary

DRACO has been used to model three different planar-foil experiments

- Planar-foil experiments can provide a measure of laser imprint and aid in the study of Rayleigh–Taylor (RT) growth mitigation.
- *DRACO* has been used to model three different planar-foil experiments:
  - Mass modulated targets: A laser prepulse can be used to increase ablation velocity and reduce the RT growth rate.
  - Buried aluminum layer: *DRACO*, postprocessed with Spect3D, shows the persistence of aluminum absorption lines, due to a wide range of temperatures in the aluminum layer, consistent with experimental measurements.
  - Doped-plastic foils: Silicon-doped plastic simulations indicate that burnthrough occurs earlier in a nonuniform drive, consistent with experiments, and at the tips of the spikes.

Outline

DRACO has been used to model three different planar-foil experiments

- Description of *DRACO*
- Description of the Spect3D postprocessor
- Experiments modeled:
  - mass-modulated targets
  - adiabat measurements
  - burnthrough measurements

DRACO is a multi-dimensional hydrodynamics code used for direct-drive ICF research

- *DRACO* uses the ALE (arbitrary Lagrangian–Eulerian) formulation to solve the hydro equations.
- Physics modules to enable *DRACO* to simulate planar direct-drive experiments have been added:
  - second-order rezoning
  - interface tracking
  - mixed-material EOS
  - laser-energy deposition
  - radiation transport

TC5234a

Spect3D[1] is used to post-process *DRACO* data

- Spect3D computes high-resolution spectra, fluxes, XRD signals, and framing-camera images.
- Material radiative properties can be modeled using
  - DCA (detailed configuration accounting):
    - LTE (local thermodynamic equilibrium) or non-LTE atomic-level populations computed explicitly;
    - b-b, b-f, and f-f opacities/emissivities computed on-line;
    - used to obtain spectra of low- to mid-Z elements.
  - non-DCA:
    - atomic-level populations not computed on-line;
    - opacities from LTE or non-LTE multigroup opacities;
    - generally used for higher-Z materials.

[1] J. J. MacFarlane, A. Thomas-Cramer, K. Park, and P. Zeng, Prism Compuational Sciences Report, PCS-R-011, Madison, WI (2000).

Spect3D[1] is used to post-process *DRACO* data (cont.)

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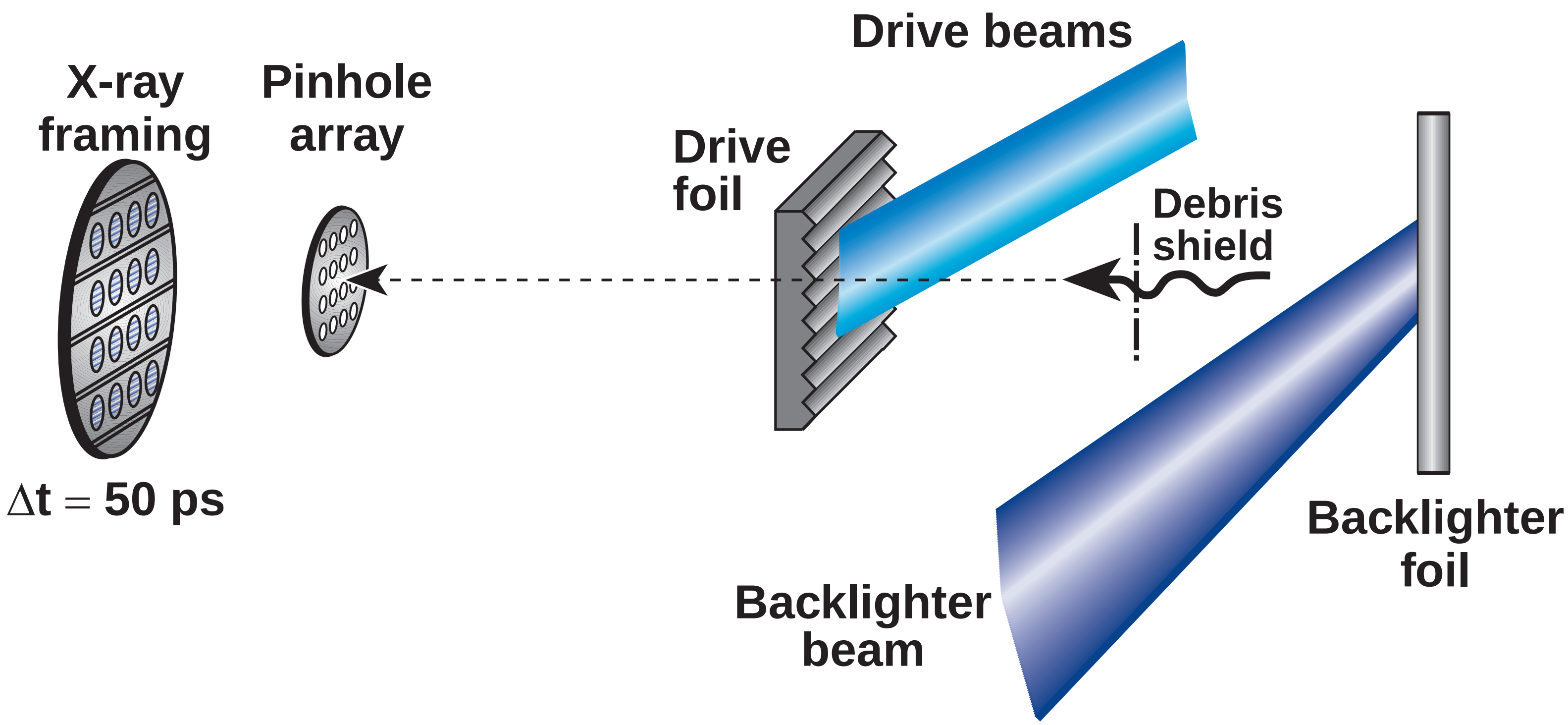
- Radiative transfer along "lines-of-sight" is computed using an integral transport.
- Line shapes include effects of natural, Doppler, Stark, and Auger broadening.
- The use of detailed atomic modeling is supported; that is, satellite line emission/absorption, forbidden/intercombination transitions, and inner-shell transitions can be included for spectral calculations.

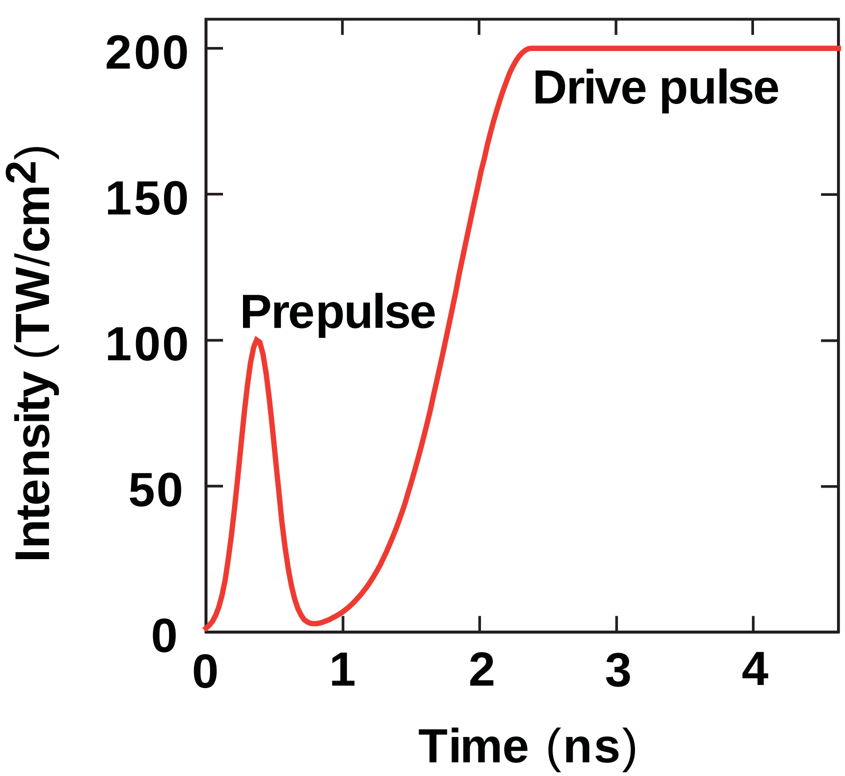
[1] J. J. MacFarlane, A. Thomas-Cramer, K. Park, and P. Zeng, Prism Compuational Sciences Report, PCS-R-011, Madison, WI (2000).

Experiments on mass-modulated targets accelerated with and without a prepulse were simulated by *DRACO*[1]



[1] CO2.003

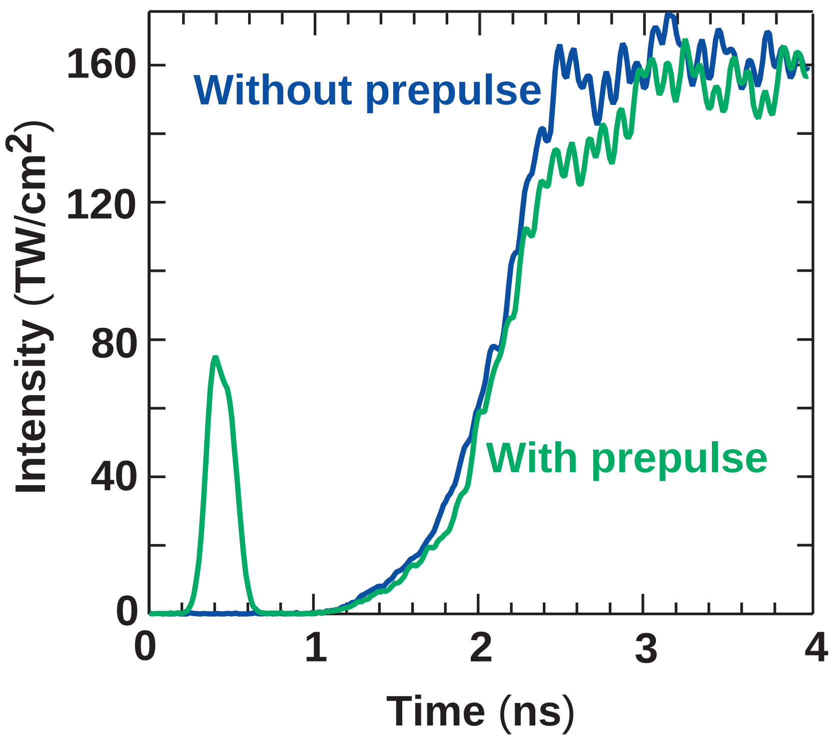
Laser prepulses have been used to lower Rayleigh–Taylor growth in planar targets



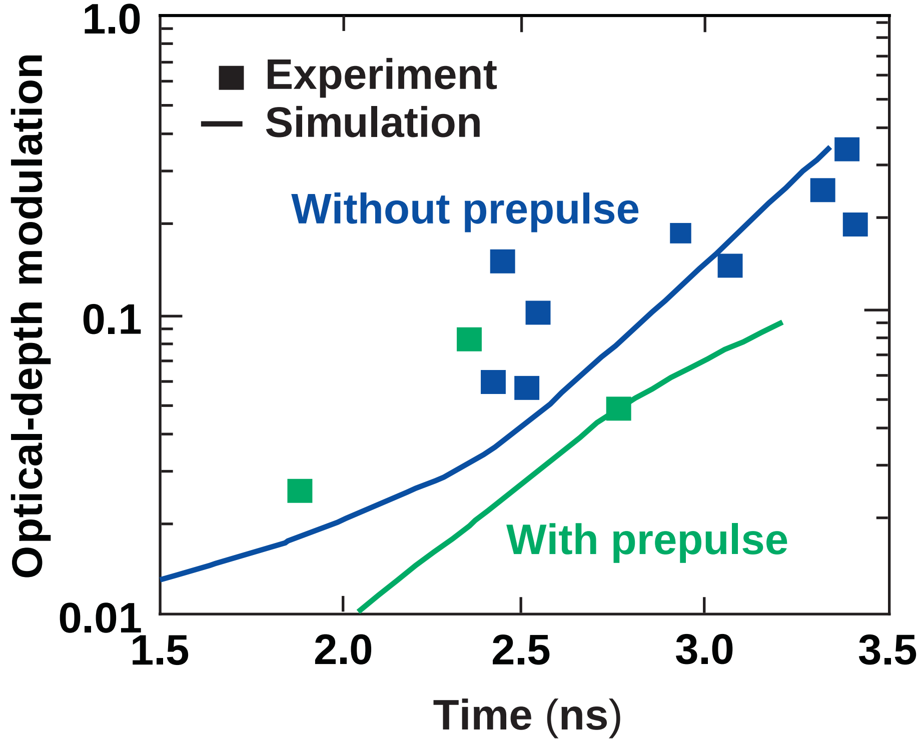
- The prepulse shocks and preheats the target.
- The relaxation period allows the target to decompress.
- The lower peak density during the drive pulse results in a greater ablation velocity.
- Ablative stabilization lowers the Rayleigh–Taylor growth rate.
- Experiments in Feb 99 and May 00[1] have been successfully simulated by *DRACO.*

[1] CO2.003

The prepulse shocks the target, resulting in a smaller Rayleigh–Taylor growth rate



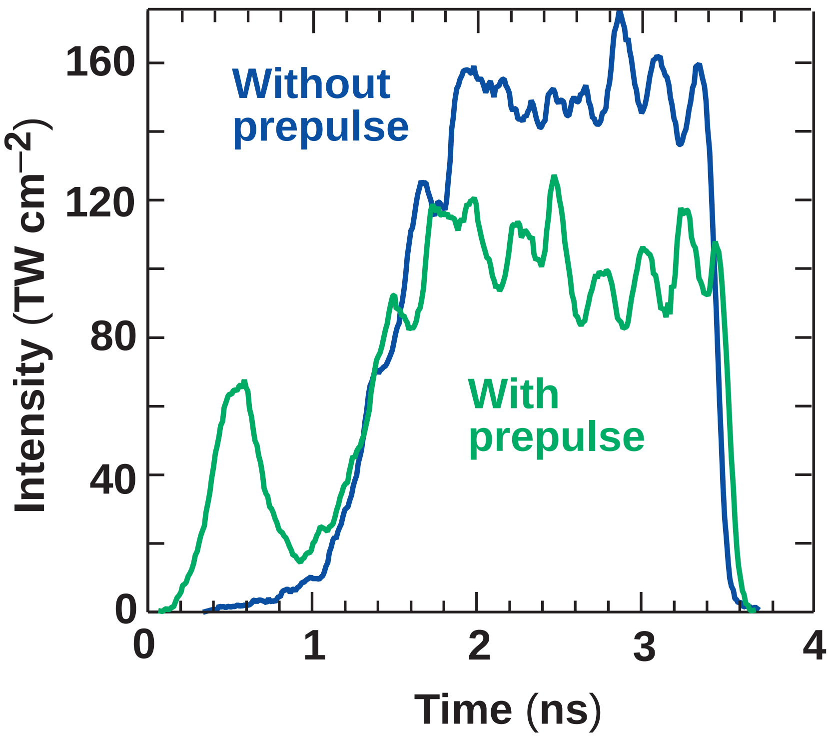
60-μm perturbation

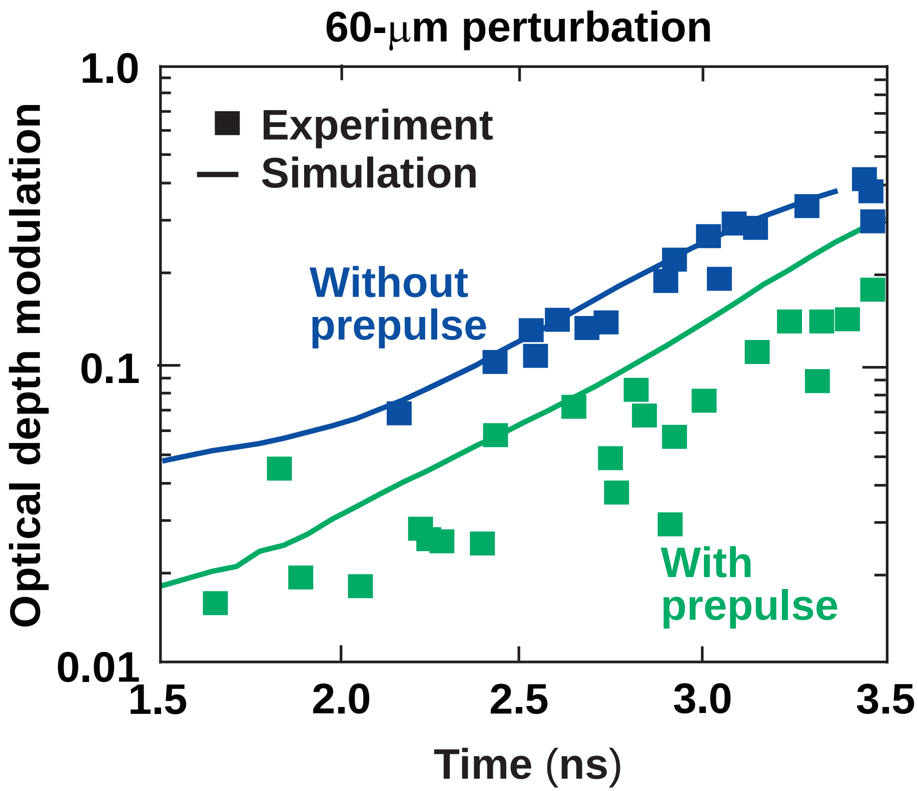


TC5456

Growth-rate modification depends on the prepulse

- Modification of the growth rate is sensitive to the prepulse intensity and the relaxation time between prepulse and drive pulse.
- When these are too small, the growth rate is largely unchanged.

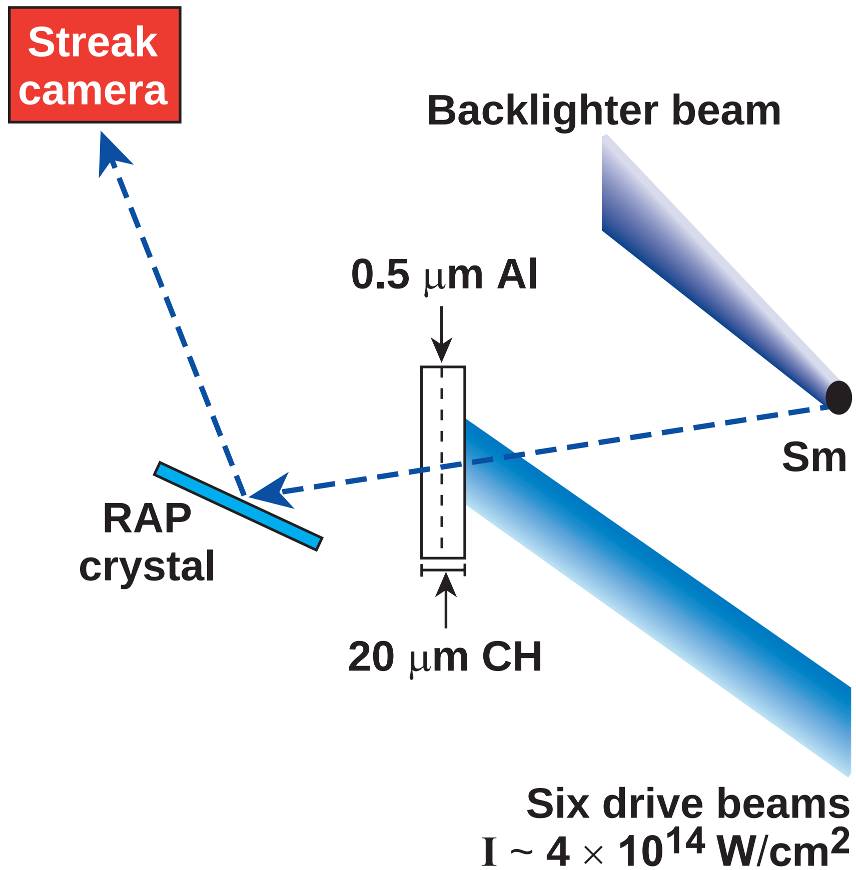


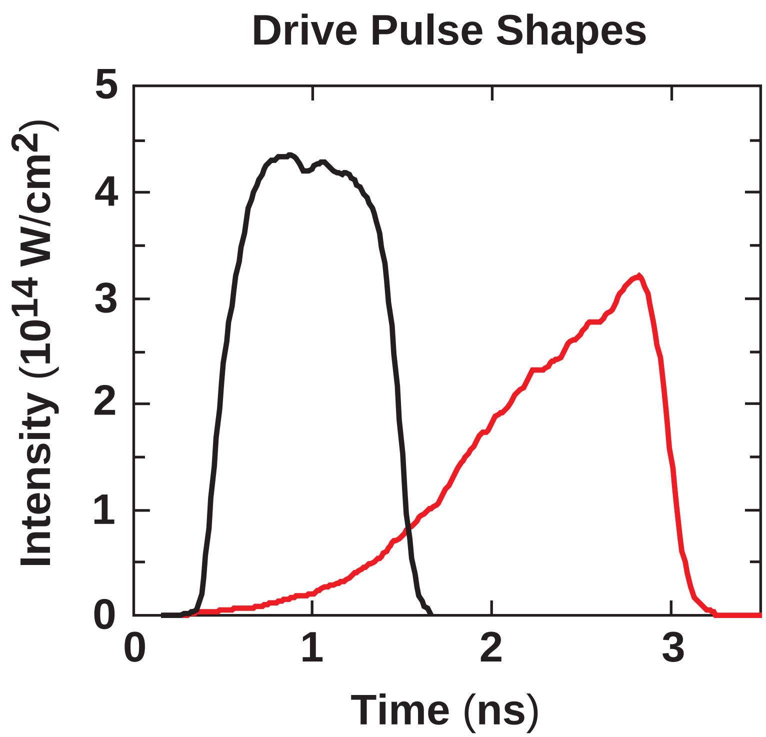


TC5579

Adiabat measurement

X-ray absorption spectroscopy is used to study shock heating produced by square and ramp pulses[1, 2]



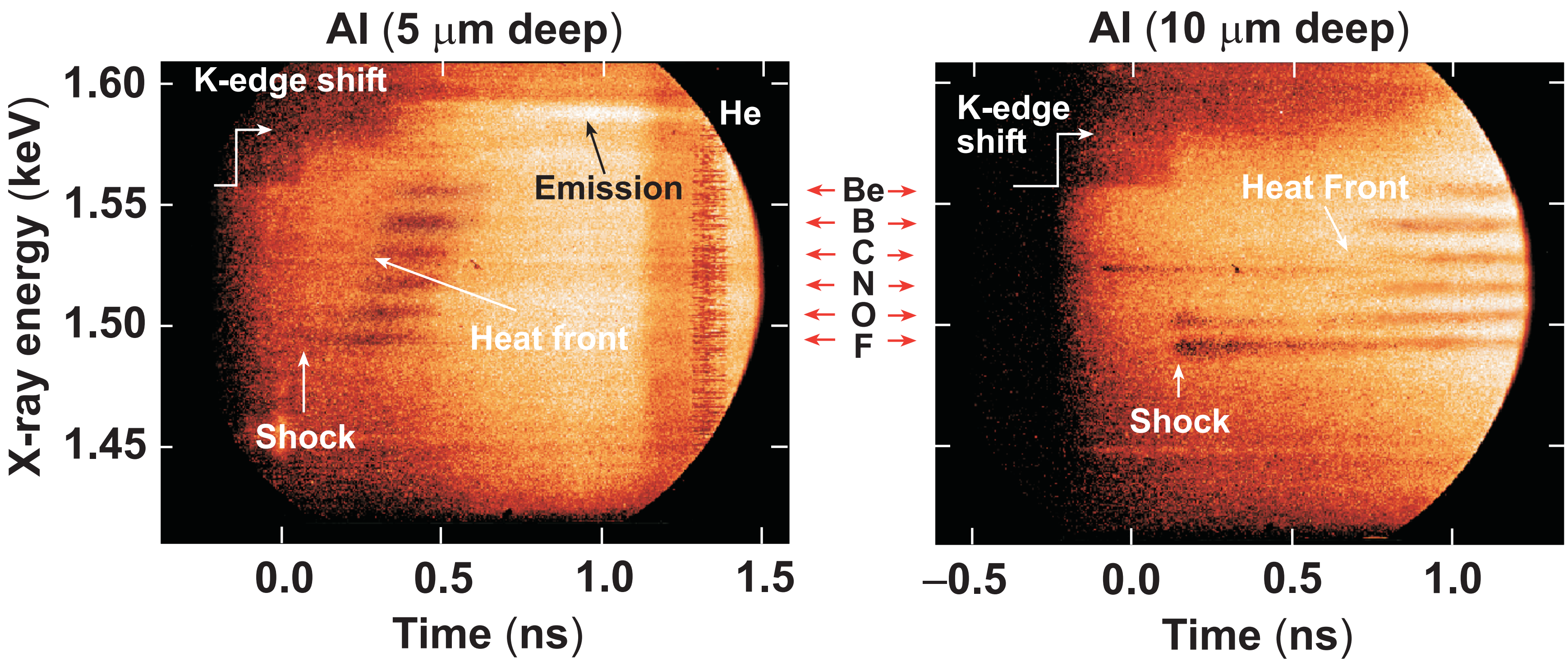


[1] MO2.010, [2] MO2.011

E10402b

The persistence of absorption lines depends on the depth of the Al signature layer

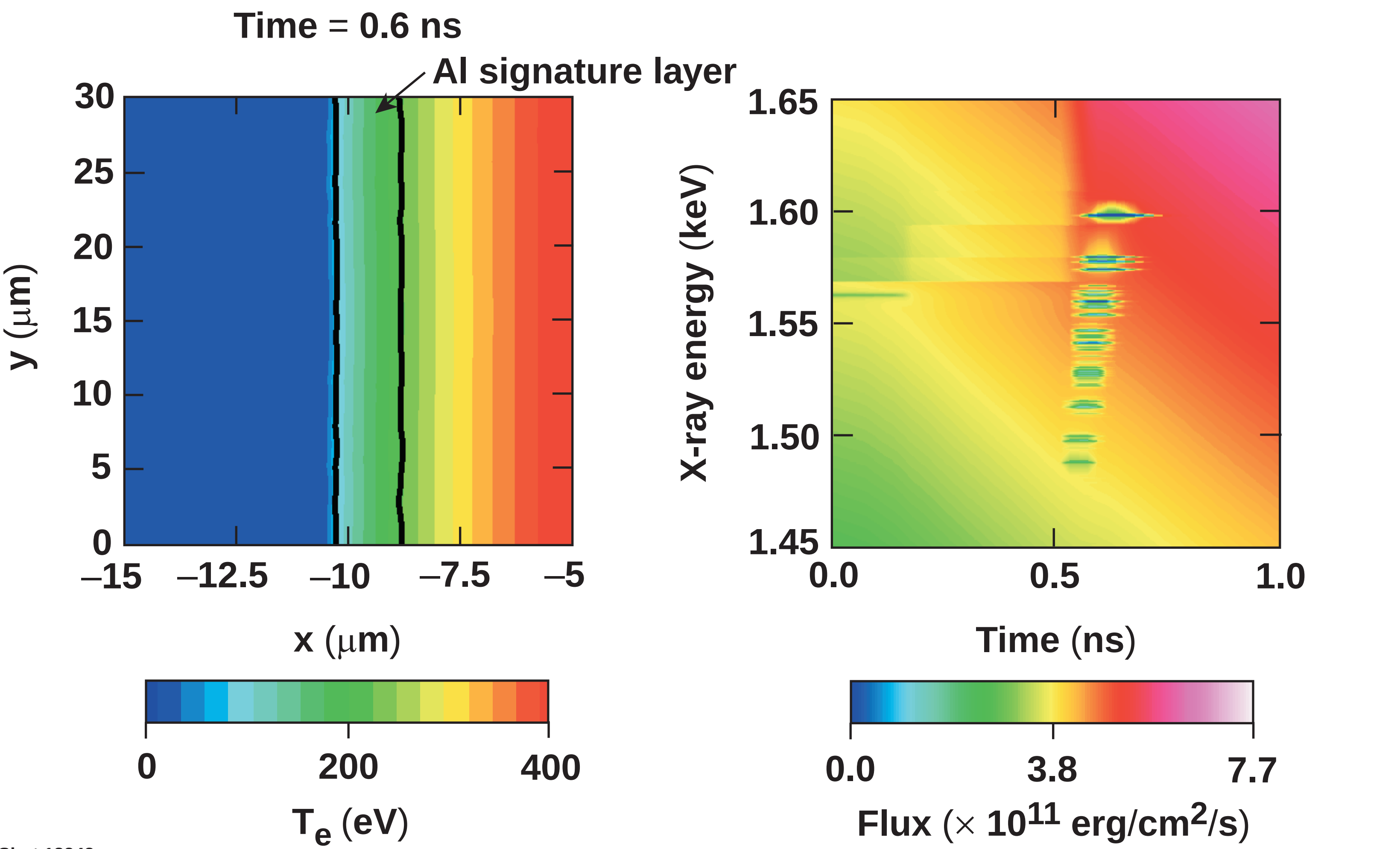
Square pulse



S18243, S18244
E10346a

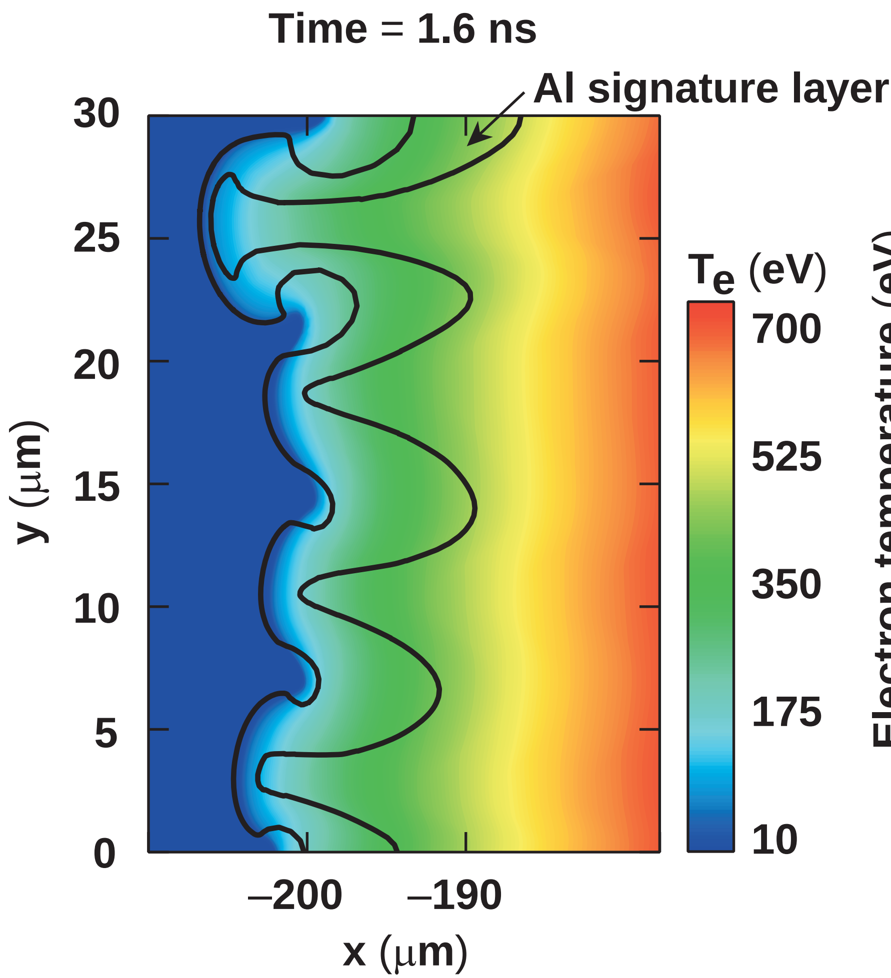
An Al signature layer buried 5 μm deep shows a staircase progression in the absorption lines

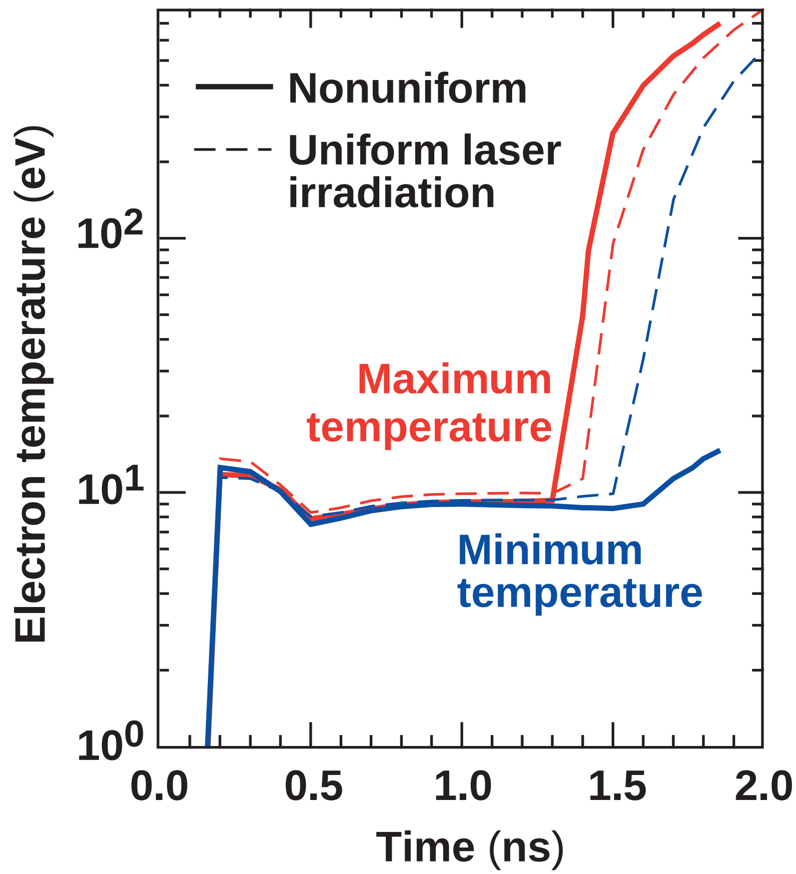
- The signature layer moves uniformly into the ablation region.



Shot 18243
TC5581

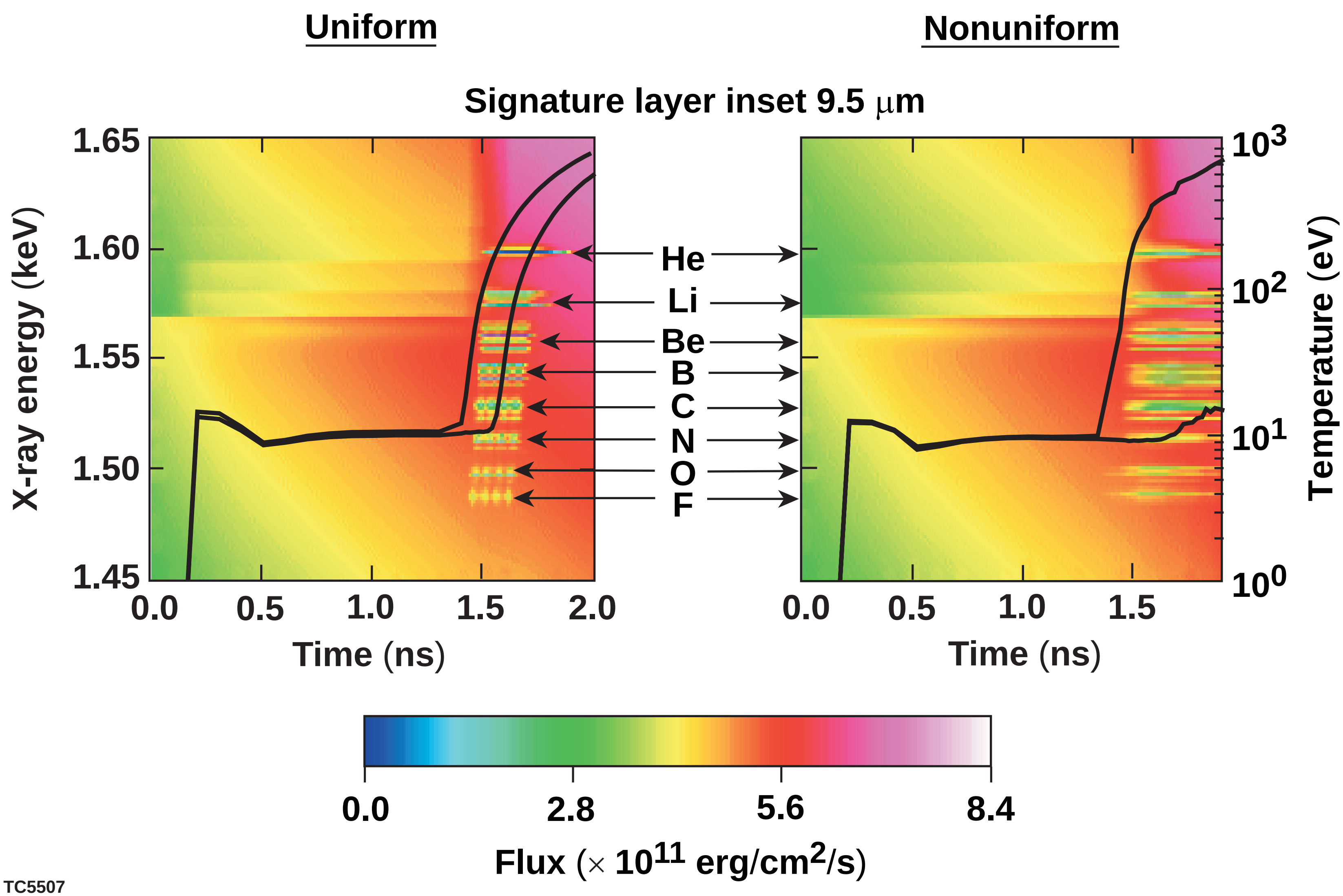
DRACO calculations show that when buried 9.5 μm deep the signature layer has a range of temperatures





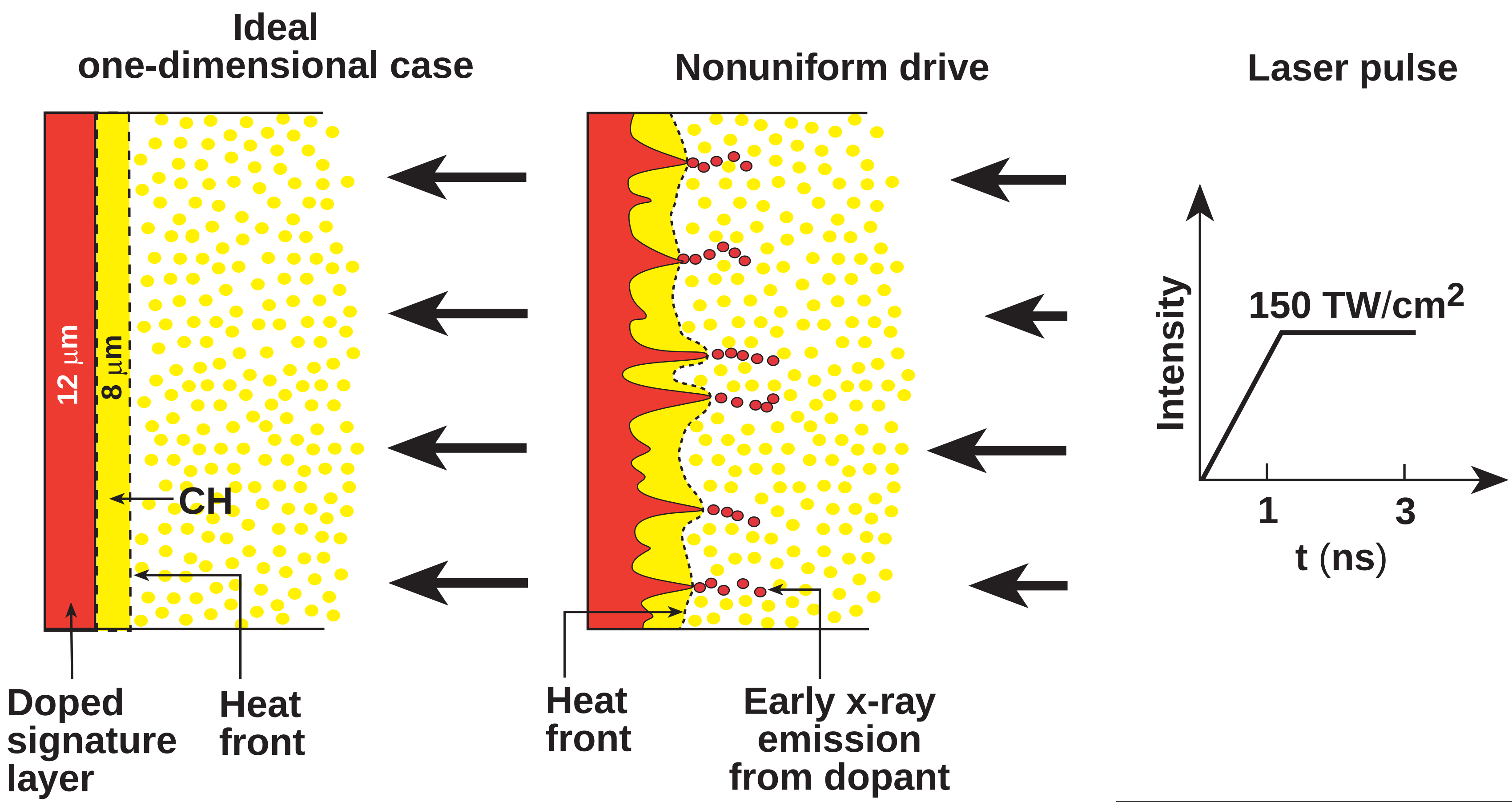
TC5452

Simulated spectra of an Al signature layer show differences between uniform and nonuniform illumination



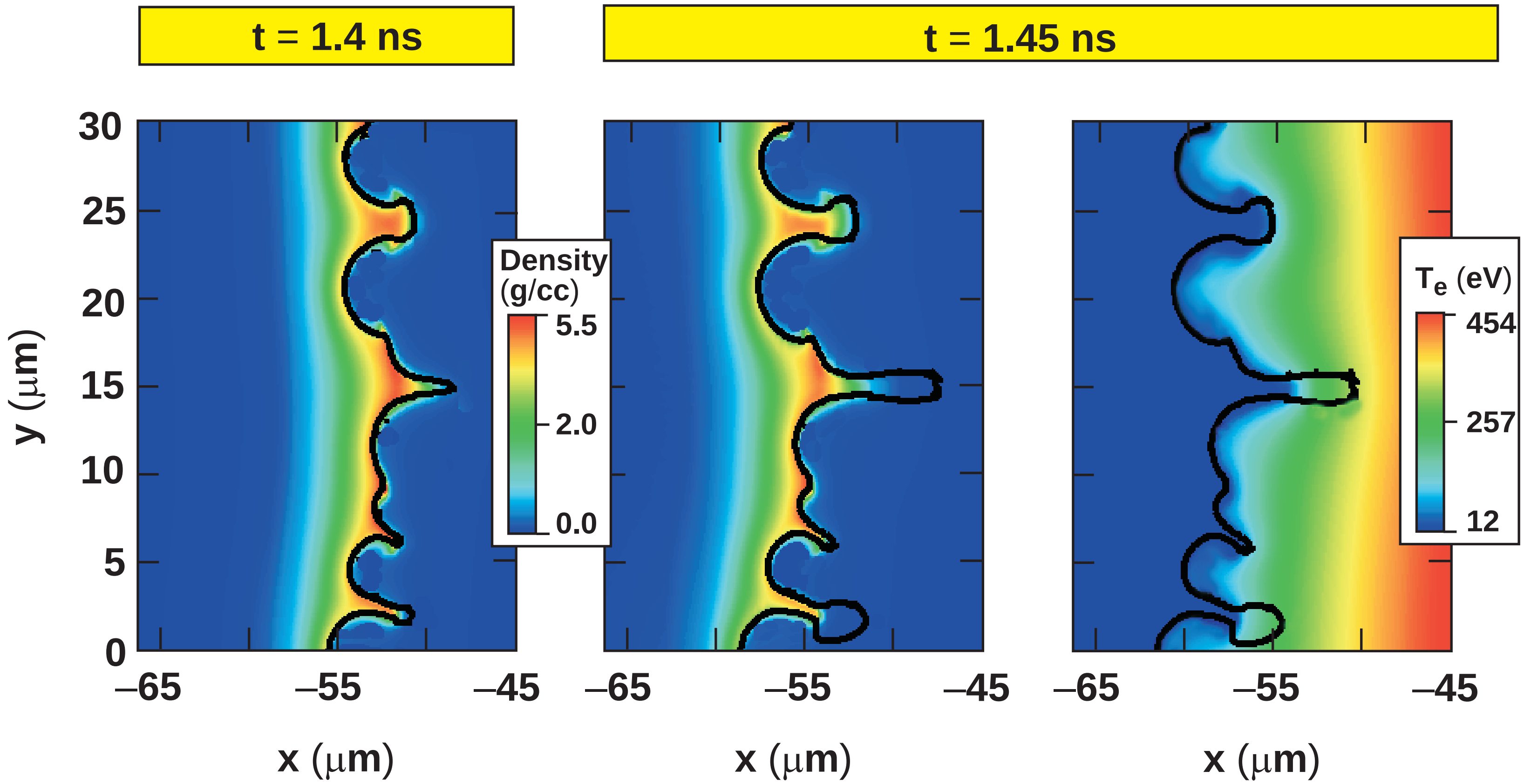
TC5507

The RT growth of accelerating foils has been examined using the burnthrough technique[1]



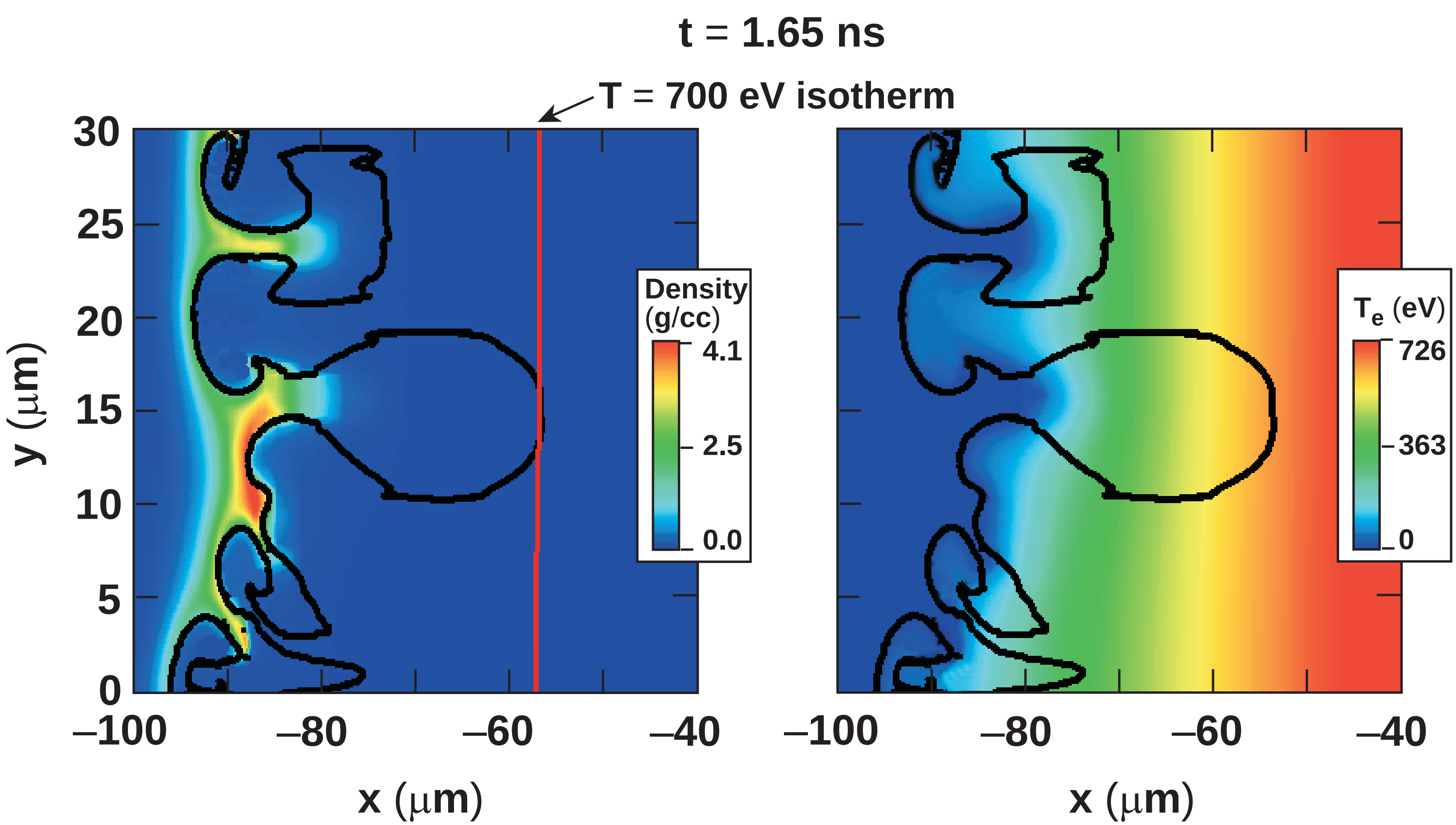
[1] MO2.008, MO2.009

The doped material moves to the tips of the spikes before it is ablated



TC5454

DRACO simulations indicate that burnthrough occurs at the tips of the spikes



Burnthrough in 1-D occurs at 2.45 ns, much later than in 2-D.

TC5453

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